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The Disease-Free Wall in Coronary Atherosclerosis: Its Relation to Degree of Obstruction

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Coronary atherosclerotic lesions are more often located eccentrically (70%) than concentrically (30%). In this study, the configuration of eccentric coronary artery atherosclerotic lesions was assessed by means of computerized planimetry in 100 specimens of eccentric arterial lesions. Special attention was given to the relation between the disease-free wall and the severity of obstruction. The mean disease-free wall arc length measured between 17 and 23% of the total vessel circumference in eccentric coronary artery lesions that obstructed 50 to 90% of the cross-sectional area. This ratio persisted irrespective of the location of the lesion within the vessel and was not significantly different with vessels of different sizes. The presence of disease-free arcs of coronary artery wall as observed in this pathologic study may relate to three factors in clinical coronary artery disease: 1) The published observations of spasm in segments of arteries harboring structural obstructive lesions may be explained by the frequent presence of uninvolved arcs of coronary artery walls. 2) Multiple views during coronary arteriography are necessary to accurately reflect the degree of obstruction. 3) The results of percutaneous transluminal coronary angioplasty may be influenced by both the disease-free arc and the atheromatous obstruction.

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Advances in the diagnosis and therapy of ischemic heart disease have renewed interest in the configuration of the coronary artery atherosclerotic lesion. The intimal lesions of atherosclerosis characteristically involve one arc of the vessel, while circumferential involvement of the vessel is less common. In a review (1), of histologic sections of 200 coronary artery segments, a circumferential distribution of the atheroma (*concentric* type of lesion) was found in 30% of the sections (Fig. 1a). In 70% of these sections, the atheroma failed to involve all of the circumference of the vessel, and the resulting narrowed lumen was *eccentric* (Fig. 1b and c).

The purpose of this study was to analyze the geometry of eccentric coronary artery atherosclerosis by means of computerized planimetry to determine the relation between the disease-free wall and the atheroma. The geometry of eccentric coronary atherosclerotic lesions has major implications for: 1) a potential change in luminal diameter in response to either spasm or dilation of the disease-free wall, 2) the accuracy with which coronary arteriography reflects the degree of luminal obstruction, and 3) the mechanism of percutaneous transluminal coronary angioplasty.

Methods

Materials. The pathologic specimens in this study were obtained from the Cardiovascular Registry of United Hospitals. We chose 100 sections of coronary arteries from the randomly selected series described by Vlodaver and Edwards (1), in which an eccentric type of lumen was present. Sections were limited to those from the proximal and intermediate portions of the major coronary arteries because such segments are important when considering coronary angioplasty or coronary artery surgery. The study was also limited to those eccentric lesions obstructing more than 50% of the cross-sectional area.

Morphologic study. For the purpose of this study, each artery was divided into segments. The anterior descending artery was divided into a proximal segment (from the origin to the first diagonal branch) and an intermediate segment

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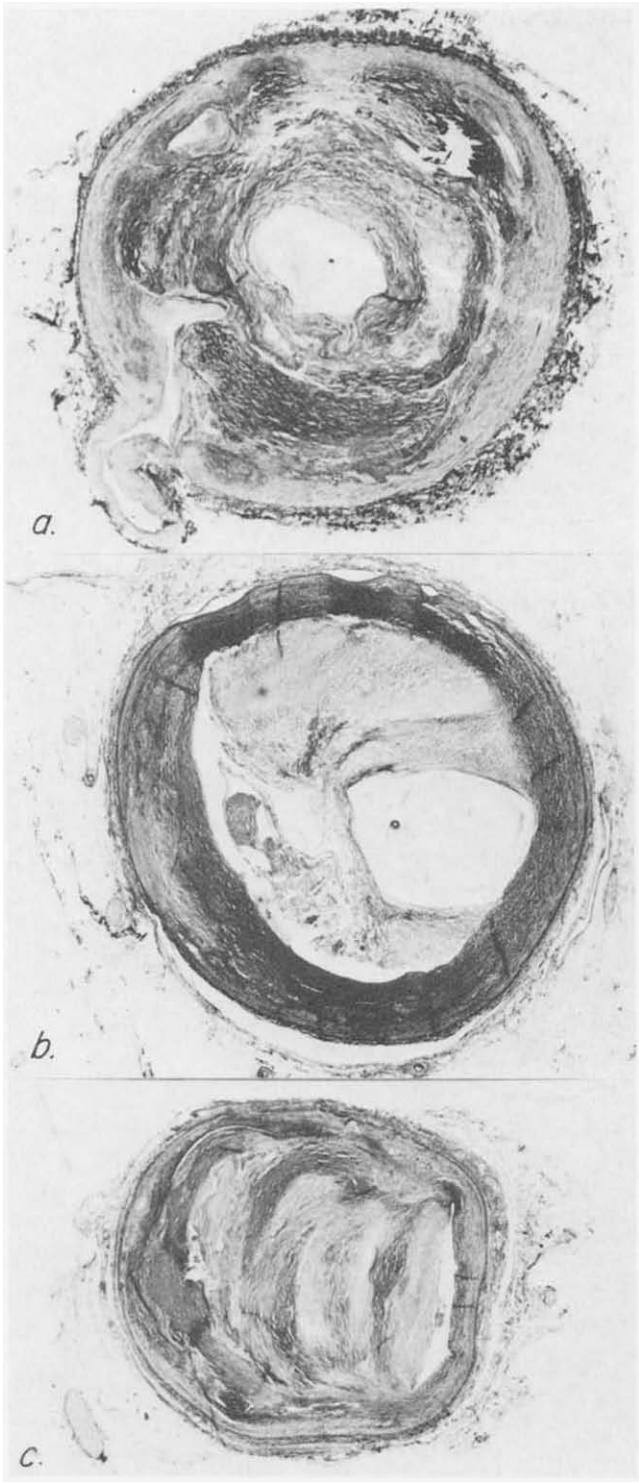


Figure 1. Three types of lumina seen in coronary atherosclerosis. **a**, Concentric lesion, central and circular lumen. Elastic tissue stain, × 15. **b**, Eccentric lesion, polymorphous lumen. Elastic tissue stain, × 22. **c**, Eccentric lesion, slit-like lumen. Elastic tissue stain, × 22. Panels **a**, **b** and **c** have been reduced by 20%.

(between the first and the second diagonal branches). The right coronary artery was divided into a proximal segment (from the aortic origin to the marginal branch) and an intermediate segment (from the marginal branch to the origin of the posterior descending artery). Sections of the circumflex coronary artery between its origin from the main left artery and the origin of its marginal branch were studied.

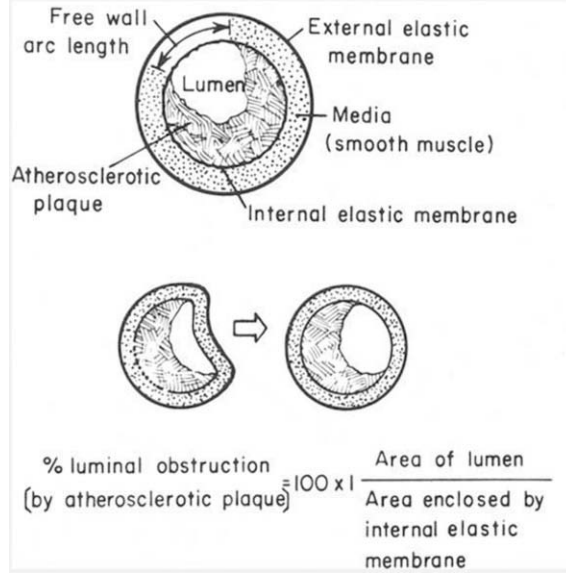
The extent of luminal obstruction was assessed by the degree of luminal obliteration within the circle bordered by the internal elastic membrane. Specimens were used only when there were sufficient characteristics to identify the location of the internal elastic lamina and, thus, the boundary of the original coronary artery lumen could be identified from histologic sections stained for elastic tissue. When the uninvolved segment of the wall was collapsed, the measurement of the degree of narrowing was made only after visual outward expansion of the collapsed portion of the arterial wall (Fig. 2). Although the effects of fixation and processing cannot be entirely eliminated, this appears logical because slit-like lumina seen in prepared sections were probably ovoid during life.

Photographs were taken from the sections and then magnified 22 times by light microscopy. The photographs were digitized on a Hewlett-Packard 9845A digitizer. XY coordinates were analyzed with a Hewlett-Packard 9845A desktop computer. Original vessel perimeter, vessel area, unobstructed area and free-wall arc lengths were calculated. Area was determined by the following formula for an area of a polygon:

$$\text{Area} = \frac{(X_1 + X_2) \cdot (Y_1 - Y_2) + (X_2 + X_3) \cdot (Y_2 - Y_3)}{2} \quad (cont.)$$

$$+ \frac{\cdots (X_n + X_1) \cdot (Y_n - Y_1)}{2}.$$

Figure 2. Planimetric procedure employed in measuring the percent obstruction of the cross-sectional area and the free wall arc length in coronary artery cross sections. If the uninvolved segment of the wall is collapsed, the measurement is made only after visual outward expansion of the collapsed wall segment (**open arrow**).



Results

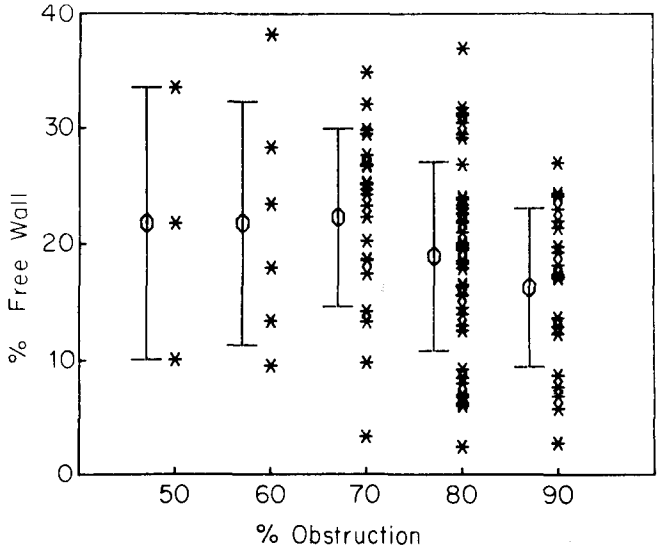
Two types of eccentric lumina could be described: 1) a slit-like lumen (Fig. 1c), and 2) a polymorphous lumen that varied in shape, being circular in some instances (Fig. 1b), as previously described (2,3).

Relation to obstruction. In each specimen with eccentric coronary artery atherosclerosis, the percent of obstruction of the cross-sectional area was compared with the percent of disease-free wall arc length of the total vessel circumference (Fig. 3). Most of the arteries were obstructed 60 to 90%. In this group the disease-free wall arc length was between 2.4 and 38% of the total circumference (mean 23% for 60 to 70% obstruction, 19% for 71 to 80% obstruction and 17% for 81 to 90% obstruction). Although there was a tendency to have a lesser percent of free wall arc length in vessels with more severe obstruction, this difference was not significant. Furthermore, the percent of free wall arc length exceeded 30% of the total vessel circumference in only eight vessels obstructed more than 50%.

The disease-free wall arc length as a percent of total vessel circumference was not significantly different for any of the arterial segments analyzed (proximal right, intermediate right, proximal left anterior descending, intermediate left anterior descending and left circumflex coronary arteries). Thus, a mean value of 20% of the total vessel circumference remained as a disease-free arc among the arterial segments studied.

Size of vessel. To determine whether the geometry of eccentric coronary atherosclerosis is influenced by the size of the artery, we compared lesions from arterial segments of different diameters. The internal diameter bordered by the internal elastic membrane was between 1.5 and 4.5 mm in our sections. The percent of disease-free wall arc length for the different vessel diameters is indicated in Figure 4, showing that there was no difference with variations in vessel size. Therefore, vessel diameter did not appear to influence the percent of disease-free wall.

Figure 3. Ratio of disease-free wall arc length to total vessel circumference compared with severity of obstruction of coronary artery lumen (*single values, mean value ± SD) in 100 cross sections of eccentric coronary artery atherosclerosis. % Free Wall = percent of the uninvolved wall of total vessel circumference; % Obstruction = percent of the obstruction of the cross-sectional area of coronary artery lumen enclosed by internal elastic membrane.



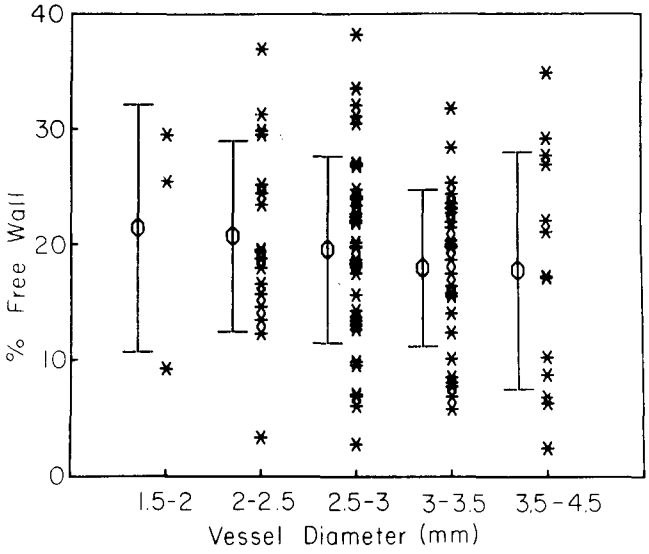


Figure 4. Ratio of disease-free wall arc length to total vessel circumference for different vessel diameters (*single values, mean value ± 1 SD) in 100 cross sections of eccentric coronary atherosclerosis. % Free Wall = percent of the uninvolved wall of total vessel circumference; Vessel Diameter = diameter of cross-sectional area enclosed by internal elastic membrane.

Discussion

Our results indicate that in clinically important coronary atherosclerosis the major part of the arterial circumference is occupied by solid atheromatous material and, therefore, only a small part of the arterial wall is found to be free of disease. Although there was a wide range, the mean disease-free wall arc length in vessels with luminal obstruction greater than 50% represented 17 to 23% of the total vessel circumference. This ratio persisted irrespective of the location of the coronary artery lesion and was not significantly different with variations in vessel size. These findings may relate to 1) our understanding of the coronary circulation in ischemic heart disease, 2) the accuracy with which coronary arteriography reflects the configuration of the diseased vessel, and 3) the possible mechanism of percutaneous transluminal coronary angioplasty.

Vasomotion. Previous studies (4–7) demonstrated angiographically that a changing caliber of the luman may occur at sites of organic coronary artery obstruction. The authors suggested that the changing caliber results from

spasm. In our pathologic study, we observed in vessels with eccentric lesions that the arc of the arterial wall occupied by solid atheromatous material appeared to be firm and not likely to change configuration in response to humoral or neurogenic stimuli. The normal or nearly normal arc, however, appeared to be capable of reacting to such stimuli. The changing luminal caliber of diseased arterial segments described by several investigators may result from changing tone in disease-free arc segments such as those observed in this study.

Coronary arteriography. The correlation between arterial obstruction found at coronary arteriography and at autopsy is, in general, quite good. Some studies (8–10), however, have suggested that the degree of obstruction may appear less severe by coronary arteriography than in pathologic sections. This may be due to two factors: 1) The size of the lumen may decrease when intraarterial pressure has decreased after death and the tissue is fixed in formalin, and 2) the arteriogram displays the vessel longitudinally, while cross-sectional views are not available. Thus, if the narrowed lumen is silt-like or ovoid in shape, the arteriogram reveals only a slight reduction in diameter of that vessel although, in fact, it may be severely stenotic (11). This has led to the widespread practice among angiographers of obtaining multiple opposing views of each vessel.

Percutaneous transluminal coronary angioplasty. The mechanism of luminal dilation during percutaneous coronary angioplasty is not completely understood. Three major mechanisms have been suggested to occur either alone or in combination: 1) expansion of the circumference of the artery by fracture of the plaque and separation of the intima from the media, 2) a change in configuration of the atherosclerotic lesions, and 3) stretching of the disease-free arterial wall (12–16).

The portion of the arterial wall that appears capable of stretching would consist mainly of the disease-free wall. This mechanism might explain some instances of restenosis subsequent to coronary angioplasty. In such cases, the disease-free wall would be stretched during angioplasty, resulting in a greater vessel diameter; then, in the ensuing weeks or months, the disease-free arc might return to its original dimension with resultant restenosis.

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